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THE RELATION OF RESEARCH TO THE PROGRESS OF MANUFACTURING INDUSTRIES

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We humans can never quite appreciate the incredible applicability and utility of new facts of nature. We are repeatedly shown by our experience, but each new example only augments our stock of wonderment or bewilderment. A very few months ago a certain well-known scientific investigator (Lord Rayleigh) found a slight difference in the density of nitrogen taken from air and nitrogen derived from other sources. He felt obliged to know about this little difference. In coöperation with Sir William Ramsay, he discovered argon. This was present in the atmospheric nitrogen and had always escaped detection. It formed less than one per cent of the air. It was discovered to be entirely inert and chemically inactive. This was an apparent promise of great chemical uselessness. At that time it was also exceedingly difficult to separate it from the air, and except for its scientific interest, it seemed destined to be left inactive. Newly discovered methods of liquefying air and of combining nitrogen for fertilizer, as in the cyanamid process, have just made the argon available commercially. Other pure scientific research had shown the value of such a gas in incandescent lamps, and it is just at this time being used to produce the most efficient incandescent lamps of our knowledge. It was the recently discovered differences between this gas and other gases which made this lamp possible. When its existence and properties were known, its application was relatively simple and easy.

Our American people are quick to see the value of new things where value exists. They are given, in this era, to actively utilizing every scheme which means better health, greater safety, greater pleasures, greater profits, and greater economies. We can hardly conceive of a people devoting their lives to inactivity and idleness. To better living conditions, to improve and extend manufacturing industries, and to conserve resources is quite generally the life aim of our ablest men.

A nation or a race does not stand still. It either advances or falls behind its neighbors. Knowing more has been the means of every nation's advance.

Research is a convenient word which covers the pioneer work upon which advances are founded. It is significant that as life becomes more and more complex, it is ever less possible for advances to be made by accident or by the designs of an individual working for short periods on different subjects. The day of that inventor is past who discovers an animal carrying a new hide, who modifies the shoe machinery or devises a new button or buttonhole. Each of these and a thousand other such details are now the fertile fields in which groups of trained experts are at work. We want shoes badly and there are many of us. We want them to wear well, even to the enamel on the brass eyelets. The fact that we are collectively willing to pay hundreds of thousands, or even millions of dollars for some slight improvement in a shoe or additional economy in the manufacture, indicates not only that we are many, but that we want actively every possible improvement and economy.

A Benvenuto Cellini lived and left the impression that he did all the work of an army of artists, inventors, soldiers, politicians, murderers, and—I may as well add—biographers. Besides his autobiography, he wrote books on the goldsmith art, sculpture and bronze, foundry practice, architecture, and poetry. There are none extant like him.

A Franklin wrote equally advanced discourses on electricity, on coal stoves, on the recently united states of America which he represented, on economy, on philosophy, and many other subjects. We have few Franklins and Cellinis today.

Today the research chemist, with his analytical methods, the metallographist, with his microscope, the physicist with his pyrometer, the mechanical engineer with his tensile strength apparatus, and the coke, gas, oil and electric furnace experts are each separately working on the still wonderfully complex cast iron of which a stove is made. Certainly they will not be satisfied, nor will we, the people, be satisfied, with any final state, so long as we can conceive of a better one. Iron must cast better, must rust less, be stronger, be permanent in the grate bar, be cheaper, keep an unaltered color, and so on.

The entire work involved in developing such new devices and

processes may be called research, but there is a part of it which deserves more careful attention than the rest. This part is sometimes called pure research. Most people mean by this term the search after new knowledge, without reference to its utility. Others mean the search for new and useless knowledge. There certainly are searchers after new truth who do not wish to see the usefulness of their disclosures. But facts of nature or true principles of science live forever and are sure to be useful. The attempt at worship of pure research for its own sake, as is often done, is merely the tipping backward of those who wish to stand erect, unbent by sordid aims in their search after truth.

Bergson points out that the essential object of science is to enlarge our influence over things. He says:

> Science may be speculative in its form, disinterested in its immediate ends; in other words, we may give it as long a credit as it wants. But however long the day of reckoning may be put off, some time or other payment must be made. It is always then, in short, practical utility that science has in view.

A fair example of scientific research lies in the history of our talking at a distance. First, we called out as loudly as we could and the strongest voice was the best telephone. The use of some new knowledge which was not immediately or obviously connected with the voice was later put to use, and a tin or iron pipe was used for short distances as a speaking tube. After this idea was disclosed, plumbers, tinsmiths, or pipe fitters could do the rest. Then, later, the possible application of formerly entirely undreamt of principles to the increase of the speaking distance was tried. Those to which I refer were the electromagnetic principles which, in short, produced the telephone transmitter and receiver. These changed the short, thick pipe into a long, thin wire. I regret that I cannot go into detail to point out the extended researches which, without the slightest premonition of telephony, had to be made before the knowledge was at hand to enable Bell to contribute his part. Joseph Henry, for example, studying in the basement of an Albany school, had to wind wires with insulation and study the properties of the magnet, and this had to be followed by the studies of many others for half a century. To the early art, in the pipe stage, the telephone wire may have looked merely like a more refined pipe of the same material, but it was not. There were entirely new, and

what I may call remote, principles, brought into play and added to the metal of the pipe. These were discovered by patient scientific research of the highest order. The outcome could not have been foreseen from any knowledge of pipes or piping. In a practical treatment of the subject of Research and the Industries, this point must be made clear. The final gathering of the fruits of the labor of research often seems as little anticipated by the real planting done by search for new knowledge, as the picking of the fruit of a tree seems anticipated by burying a seed in the ground. Nevertheless, the developments are the same in the two cases. It may be for this reason that the President of the Carnegie Institution, in his 1914 report, referred to the work of the Institution in the words:

> The general reader must take it for granted (provisionally, at least) that these investigations are in the main worth undertaking . . . . for in proportion as such investigations are fundamental, and hence worth carrying on, they will be difficult of exposition and more difficult of comprehension.

Of the lines of activity of that Institution, the farmer sees value in the studies in heredity in cattle, but wonders why anyone should want to synthesize rocks; the glass maker who sees value in the geophysics work, wonders why the sun spot work is of use, while the naturalist[1] says: "The sublime ideas of infinity of space and time, and the beauty of the simple laws of planetary motion, have had a value to mankind far transcending that of any so-called practical application of stellar science." Thus, those who have had the broadest comprehension have generally most highly valued pure research.

So we are now in our day apparently seeing our telephone wire grow finer and longer. Talking from New York to San Francisco is a thing of every day commercial experience. This, in turn, was due not alone to the use of longer wire or lower resistance or more delicate instruments (what Bacon calls an increase in the efficient), but involved new, remote ideas, the result of research. Such is the Pupin loading coil, for example, which has made long distance telephony possible. We are also aware that to all appearances the telephone wire is now being drawn so fine that it is altogether disappearing, and wireless telephony is an accomplished

[1] R. G. Harrison, President of the American Society of Naturalists, Philadelphia, 1913.

fact. This becomes possible not through finer wire drawing, but by the application of *newly discovered laws or principles of nature.* It was not even done by those who were most industrious in construction of telephones, any more than the tin speaking tube was really displaced by the tinsmith. The work was done by those already trained scientific investigators, who were learning new facts of physics or electricity which, at some stage of their work, seemed, applicable to telephonic use. This new work, this pioneer obtaining of facts which never revert to the undiscovered state, constitutes research.

Our government, among others, has schemes for the promotion of research. One of them is the patent law. If a discoverer will disclose his discovery to the public, he may exercise a monopoly of it for seventeen years. In some cases this is very encouraging, but it seems to have at least one serious defect. The discovery, besides being new, must be, at the same time, useful. With many great discoveries this is not the case. It may seem ridiculous to favor useless discoveries, but it is quite the reverse. The thing to encourage is the search and finding of new facts, principles, laws, and habits of nature; *i.e.*, additions to our knowledge without reference to immediate value. These are the surest guarantees of ultimate utility. The process of making knowledge useful is not half so difficult nor so rare as is the production of the knowledge itself. But the rewards usually go to the man who shows us the utility. For this reason we must plan better ways of encouraging scientific research. To emphasize this is the only object of this paper. It is being done to some extent. Many of those, living and succeeding under our system of advance, have realized the way the seeds have first to be sown. They have usually selected some special field where the utility to be expected from newly disclosed facts would be of greatest public good. In this spirit have been established many of those research institutions which are devoted to the health of the people, the cure of disease, etc. These are starts in the right direction and are naturally made where the need is most painful.

Of a little more remote benefit is such research work as is being carried out by the Research Corporation, from whose minutes the following abstract was made:

This far-sighted and patriotic conception found its realization through the "Research Corporation" which for administrative reasons was substituted for the Smithsonian Institution as the custodian of Dr. Cottrell's endowment. The objects of the Research Corporation as stated in its Charter are:

"To provide means for the advancement and extension of technical and scientific investigation, research and experimentation by contributing the net earnings of the corporation, over and above such sum or sums as may be reserved or retained and held as an endowment fund or working capital, to the Smithsonian Institution, and such other scientific and educational institutions and societies as the Board of Directors may from time to time select in order to enable such institutions and societies to conduct such investigations, research and experimentation."

Organized in 1912 as a stock corporation but precluded by its charter from paying dividends and capitilized by a group of gentlemen desirous of furthering Dr. Cottrell's objects, without personal profit, the Research Corporation undertook and successfully accomplished the installation of the Cottrell processes in various industries throughout the country, with the result that in two years' operation its surplus has provided the capital of twenty thousand dollars required by its charter, and a fund of over one hundred thousand dollars for scientific research.

A few such steps as this one would soon build up a fund of new knowledge. I think it is safe to say that most of our new knowledge of physical, chemical, and electrical phenomena has come to us through the publications of various scientific societies. The work was largely done as a by-product of poorly paid services in colleges and universities of the world. Let me illustrate this point. The general field of colloid chemistry is open for investigation. There is surely no more fertile field. It touches all the reactions of living organisms and most of those of organic and inorganic chemistry, from the growth of cells through immunity to disease in animals, to the decay of metals, from the coloring of glass and dyeing of fabrics, to the production of a river delta or the manufacture of an automobile tire. It is being largely done as the by-product or hobby of a few teachers in their spare time. As the principles governing this part of chemistry are made known, the applications in useful processes will be rapid, but there are many men ready to perform the latter operation compared to the few who are making known the laws involved. For every investigator who might point out from his experiments the possibility that the antitoxic action of immunized blood serum might lie in the magnitude of the electric charges on the colloids concerned in the reactions, there are hundreds of others

who will ably test the hypothesis when it is advanced. For every chemist whose experiments go to clarify the laws of tensile strength and the wear and friction of colloidal materials, for example, there are hundreds who will test his conclusions in new aero-metals and automobile tires. We in this country are particularly active in putting the "useful" into the invention, but we are less active in the study for the "new." For this reason it is necessary to encourage research of the advanced type. Anyone who has followed the subject knows that during the past ten or more years, the amount of research work in connection with the industries has greatly increased. Large manufacturing companies in many lines have groups of men who devote all their time to advancing the methods of manufacture by more or less pure research. They are never expected to become part of the production department, but are always kept on the exploring line in laboratories. There are now research laboratories connected with almost every art and profession. The American canners and the American dentists have them, as well as the companies making powder and shot, and those making armor plates. There are laboratories devoted to research on paper and others on paint, some working on cements and others on soils, some on gas lights and others on electric lights, some on fertilizers, others on sterilizers, and some on almost everything. They could all use more knowledge to advantage if they could get it. If there were no way to increase the rate of our acquisition of knowledge, then this argument would be useless, but we have had a lesson from Germany during the past forty years which shows one way of increasing the world's stock of knowledge. It is by encouraged or endowed research. Germany did it through her universities. Every year there were turned out one or two thousand men with the degree of doctor of philosophy. This meant that each one had done a couple of years research work and, in most cases, freely published it. The stock of investigators in the country was rapidly increased. The industries and the arts felt the effects. In 1912 there were 1,703 of these doctorates conferred there, 705 were on science and 355 in chemistry. How could such a country stand still in industry? Last March, Lord Haldane, addressing a teachers' meeting in London, said:

> We are behind the level which has been reached by several of our competitors, a level which will put us in peril. We cannot dissociate national progress

from the basis of knowledge, even when it comes to the question of making money.

This conclusion is only a year old, but it is being proved.

In addition to the very helpful and important university methods of Germany, there should continue in America, beyond what is done by government laboratories and bureaus, the natural extension of the ideas exemplified by the cancer research laboratories and hospitals, the Rockefeller Institute for Medical Research, the Carnegie Institution, the Smithsonian undertakings and others.

Here also a start has been made in such work as Dr. Duncan inaugurated in the Mellon Research Laboratory at Pittsburgh and at the University of Kansas, in the very recent Brush endowed fellowships at the Nela Park laboratories, and in the Mayo brothers endowment at the University of Minnesota.

Dr. Woodward, President of the Carnegie Institution, has recently said, "Successful research requires neither any peculiar conformity nor any peculiar deformity of mind. It requires rather peculiar normality and unusual patience and industry." This certainly applies as well to the researches of an Edison, devoting his life to the immediate utilities, as to the abstract researches of the mathematician. It is for this reason that research ought to and does succeed in its applications in the case of many industries. In the industrial research laboratories, normality, patience and industry are apt to be encouraged. Interruptions are there at a minimum. Equipment, power, facilities and the rest are made a matter of some one's business. On the other hand the universities and colleges, which are forced to combine with short hours and short years the teaching of science and the methods and habits of research, are still our foremost organized research institutions. It seems possible that manufacturing companies may offer in the future nearly as great assistance to the increase of useful knowledge. Cooperation between laboratories of research in universities and industries has already been the subject of considerable study. There is a committee of one hundred of the American Association for the Advancement of Science which was appointed to encourage it. Naturally, with so great an undertaking, the progress may be slow. It is certainly possible for industrial research laboratories to economically add to scientific knowledge and to grow in the process. This fact is being recognized.

It is unfortunately true that most of what we may call the new knowledge in physical science of the past decade has had to cross the Atlantic for us. No one knows this better than those Americans who make the most use of it. The fundamental knowledge behind almost every utility which Yankee ingenuity has assisted, grew on older soil than ours. The list is almost discouraging to an American. The encouraging view to take is that we have it within our power to force the future to write different history. It is unfortunately quite safe to predict, for example, that just as most of our technical advances of the past can be traced to early fundamental discoveries in academic fields in Europe, so also we will have to see here future applications of still more modern European scientific thought. A wonderful list of useful results, processes, products, conveniences, cures and economies are sure to be produced by applications of the new knowledge of such things as radium, X-Rays, wireless waves, electrons, crystal structure, atomic numbers, canal rays, none of which were "made in U. S. A."

In physical science there is but little chance that our country will do its full share for years to come. If the wisdom of attempting it, rather than confining attention to short-sighted application of research to pressing commercial problems can be gradually recognized, the future is assured. It is surely the duty of our American research laboratories to contribute effectively in the advance of knowledge, and particularly is this true of those richly endowed with men, new materials and appliances.

And so I return to the cardinal point in any suitable consideration of research in its relation to our industries. Search for new knowledge is the insurance for the future of the industries. Many of them will later be manufacturing things not even conceivable today. The past has proved it. Most of the present products will, like the ox-yoke and flail of our grandfathers, be replaced in our factories by utilities more fitting to our new needs and less exhaustive of our energies and assets. This change is practically continuous. Technical complacency is like the mercuric chloride tablet taken internally—it means a lingering suicide. The incandescent lamp business will serve me for illustration, because I am more familiar with it than with others. I have seen whole factories entirely overhauled a number of times in the past few years, in order to make the newest lamps. Not only have entire floors of com-

plicated and expensive machines for making carbon lamps been thrown out and new machinery for making metal filament lamps installed, but before packing cases containing new machines could be opened and unpacked in the factory they have been thrown out as useless, as the advance from squirted metal filaments to drawn wire filaments proved the better way. Before the limit of factory efficiency on vacuum lamps could be reached, the introduction of nitrogen into the lamps brought the factories an entirely new factor, and now, before the consumers have more than commenced to feel the effects of the nitrogen-tungsten lamps, the manufacture of argon and its introduction into the incandescent lamp becomes a reality. If the research laboratories which discovered the means for bringing about these changes, with their corresponding economies, could tax the consuming public a cent for every dollar thus saved to the public, the laboratories would receive over a million dollars a year to spend for further research. This is not written in a spirit of dissatisfaction at all, but rather to point out what is probably true in many fields. The people are the ones most interested in research, though they may not know it. It is easier seen in therapeutic and curative research, but even there the more ignorant fail to realize the great lasting value of such work.

Bacon wrote:

> For man, being the minister and interpreter of nature, acts and understands so far as he has observed of the order, the works and mind of nature, and can proceed no further: for no power is able to loose or break the chain of causes, nor is nature to be conquered by submission: whence those twin intentions, human knowledge and human power, are really coincident; and the greatest hindrance to workers is the ignorance of causes.